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SYNONYMY OF THREE PESTIFEROUS *MATSUCOCCUS* SCALE INSECTS (HEMIPTERA: COCCOIDEA: MATSUCOCCIDAE) BASED ON MORPHOLOGICAL AND MOLECULAR EVIDENCE

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Abstract.—The scale insect genus *Matsucoccus* Cockerell (Coccoidea: Matsucoccidae) contains several economically important species that cause damage to pine trees, *Pinus* species, in the United States and elsewhere in the Holarctic Region. Efforts to reconstruct the phylogeny of the group have provided information on genetic variation within and among species. Here, three species of *Matsucoccus* are synonymized based on newly acquired molecular data and reassessment of morphological data. *Matsucoccus resinosae* Bean and Godwin, described from the eastern United States, and *Matsucoccus thunbergianae* Miller and Park, from South Korea, are considered to be **new synonyms** of *Xylococcus* (now *Matsucoccus*) *matsumurae* Kuwana. The taxonomic confusion surrounding these names is discussed. In addition, we suggest that several other species of *Matsucoccus*, including *M. pini* Green, should be investigated as possible synonyms of *M. matsumurae*.

Key Words: Margarodidae, *Matsucoccus*, red pine scale, taxonomy

Matsucoccus Cockerell is a morphologically conservative group of scale insects placed either in the scale insect family Margarodidae (Ben-Dov et al. 2005) or in its own family, Matsucoccidae (Koteja 1984, 1986; Foldi 2004). All species feed exclusively on *Pinus* (Pinaceae) and are mainly Holarctic, with limited records from the Neotropical and Indotropical regions (Ben-Dov 2005, Ben-Dov et al. 2005). This genus has received moderate taxonomic treatment (Ray and Williams 1984, 1991; Gill 1993; Foldi 2004), and 34 extant species are recognized (Ben-Dov 2005).

Recent research to reconstruct the phylogeny of *Matsucoccus* has provided the first hypothesis of species relationships based on molecular and morphological data (Booth, Cook and Gullan, unpubl. data). One relationship of particular interest is that of three pest species, *Matsucoccus matsumurae* (Kuwana), the Japanese pine bast scale, *M. resinosae* Bean and Godwin, the red pine scale, and *M. thunbergianae* Miller and Park, the black pine bast scale. New evidence supports the synonymy of the three species. Entomologists have speculated that *M. matsumurae* and *M. resinosae* are synonymous (Ray 1982; McClure 1983b, 1987; Foldi 2004). The recent catalogue of Margarodidae (Ben-Dov 2005) treats these two species separately, but mentions previous work suggesting that *M. resinosae* may be a junior synonym of *M. matsumurae* (McClure 1983a, Young et al. 1984, Park et al. 1986).

Matsucoccus resinosae infests red pine, *Pinus resinosa*, on the east coast of the United States. Red pine scale was first recognized in 1946 in Easton, Connecticut (Plumb 1950), and its rapid spread and the high tree mortality that it caused suggested that it was a new introduction (Bean and Godwin 1955). It has been hypothesized that it was introduced during the 1939 New York World Fair on exotic pines imported as a display, because the same truck that transported the exotic pines from the port was used to transport red pines from Easton to the fairgrounds (Doane 1959). The feeding cyst stage of *M. resinosae* can damage the needles, causing extensive flagging and needle drop (McClure 1976, Duda 1977). Damage is particularly severe in plantations found south of red pine's native range (Bean and Godwin 1955), apparently because low winter temperatures in the pine's natural range to the north prevent survival of red pine scale nymphs (Doane 1959; McClure 1983a, b). Damage from the red pine scale has resulted in almost complete removal of once abundant red pine plantations in Connecticut and New York states and it is now difficult to locate intact stands (J. Booth pers. observation, Providence Water Supply Board 2005).

The Japanese pine bast scale, *M. matsumurae*, has similar biology and morphology to *M. resinosae* (McClure 1976, 1983a). This scale is a pest in Asia, especially on black pine, *Pinus thunbergii* (Taketani 1972, Cheng and Ming 1979). The species was described originally by Kuwana as *Xylococcus matsumurae* (Kuwana 1905, 1907), and later transferred to *Matsucoccus* by Cockerell as the type species of his new genus (Cockerell 1909).

The third species, *M. thunbergianae* Miller and Park, from South Korea, was described as similar to *M. matsumurae* and *M. resinosae* (Miller and Park 1987). It is not possible to distinguish *M. thunbergianae* from *M. matsumurae* and *M. resinosae*, based on the adult females or the first-instar nymphs, but *M. thunbergianae* is said to differ from the other two species in the size of the adult male, in the number of generations per year, and in overwintering as the second-instar nymph (as the first-instar nymph in the other two species). *Matsucoccus thunbergianae* is univoltine or has only a partial second generation (Miller and Park 1987), whereas *M. matsumurae* and *M. resinosae* are bivoltine or have a partial third generation (McClure 1977, Miller and Park 1987). *Matsucoccus thunbergianae* is considered a pest in Korea on black pine (Miller and Park 1987, Chung et al. 2000).

Several available pieces of biological evidence support the synonymy of these three *Matsucoccus* species. First, the sex pheromones of *M. matsumurae*, *M. thunbergianae*, and *M. resinosae* have been shown to be cross attractive in bioassay studies (Young et al. 1984, Park et al. 1986). The primary component of the sex attractant was identified and the pheromone is identical for the three species and has been named "matsuone" (Lanier et al. 1989, Hibbard et al. 1991). Second, all species occur on hosts found in the same *Pinus* subsection, subsection *Pinus*, of the pine tree phylogeny of Gernandt et al. (2005). *Matsucoccus matsumurae* occurs on seven *Pinus* species (McClure 1983a), *Matsucoccus thunbergianae* only on *P. thunbergii* and *P. densiflora* (Miller and Park 1987), and *M. resinosae* is found on *P. resinosa* (Kuwana 1905, Bean and Godwin 1971, Miller and Park 1987), which is the only species of the *Pinus* subsection *Pinus* in the United States (Gernandt et al. 2005). Ray (1982) and McClure (McClure 1983b) went further and noted that *M. resinosae* and *M. matsumurae* are more specifically found only on members of the Sylvestres group of the subsection Pinus. However, the Sylvestres group is

Table 1. Specimens of adult females examined for morphological analysis.

Species Name	# Slides (# Females)	Collection Information	Depository
M. matsumurae	1 (1 non-type)	JAPAN: Kanagawa-ken, ex pine tree, 13.v.1919; Coll. S. I. Kuwana (mounted from dry material sent by Kuwana to F. B. Herbert)	BME
	1 (2 non-type)	JAPAN: Nagashima, ex *P. densiflora*, 10.v.1970; Coll. M. Inoure	BME
	2 (2 non-type)	JAPAN: Nagashima, ex *P. densiflora*, 4.v.1970; Coll. M. Inoure	USNM
	3 (4 non-type)	JAPAN: Japan: Mie Prefecture, Shimagahara Village, ex *P. thunbergii*; 24.ii.2004; Coll. T. Kondo	BME
M. pini	3 (5 paralectotypes)	ENGLAND: Oxshott, Surrey, ex *P. sylvestris*, 31.x.1922; Coll. F.C. Withycombe	BMNH
M. resinosae	3 (holotype and 2 paratypes)	USA: Connecticut, Easton, ex *P. resinosa*, 2.v.1948; Coll. George H. Plumb	USNM
M. thunbergianae	4 (holotype and 5 paratypes)	SOUTH KOREA: Kohung, Chollanam-do, ex *P. thunbergiana* (now *P. thunbergii*), collected xii.1983, lab reared iv.1984; Coll. S. C. Park	USNM
	1 (2 paratypes)	SOUTH KOREA: Kohung, ex *P. thunbergii*, collected xii.1983, lab reared iv.1984; Coll. S. C. Park	BME

not recognized in the most current *Pinus* phylogeny (Gernandt et al. 2005). Third, the distribution of *M. matsumurae*, *M. resinosae* and *M. thunbergianae* supports their synonymy. McClure (1983b) pointed out that the first two species are restricted to a similar northern latitudinal limit: 41°50′N in the U.S., 41°30′N in Japan, and 41°30′N in China. Similarly, *M. thunbergianae* has been reported only from South Korea (Miller and Park 1987), for which the northern boundary lies at about 39°N.

Here we present the first molecular data and reassess the morphological evidence to show that specimens described as *M. matsumurae*, *M. resinosae* and *M. thunbergianae* belong to the same species. We synonymize *M. resinosae* and *M. thunbergianae* under the senior synonym *M. matsumurae* and provide a new diagnosis for this species.

Materials and Methods

Morphology.—Morphological characters were evaluated and measured using a Leica compound microscope. Type material was examined for *M. resinosae* and *M. thunbergianae*, whereas subsequent material collected by the original author was studied for *M. matsumurae* (see below under "Type material"; also Table 1). Specimens from each collection were scored for 14 morphological characters (Table 3), including those previously recognized by Ray (1982). The diagnosis was prepared based on the specimens listed in Table 1. Specimens examined are housed at the Bohart Museum of Entomology (BME), University of California, Davis; The Natural History Museum, London (BMNH); and the Coccoidea Collection of the National Museum of Natural History, Smithsonian Institution (USNM) in Beltsville, Maryland.

Genetic analysis.—Molecular data were acquired for 13 specimens belonging to six named *Matsucoccus* species that the authors field collected or that colleagues donated (Table 2). Specimens were stored in 75% ethanol for slide mounting and 100% ethanol for molecular work. Genomic DNA was extracted

Table 2. Specimens used for molecular analysis.

Species Name	DNA Code	Collection Information	Coordinates	Life Stage	*Pinus* Host
M. acalyptus	JMB037	AZ Yavapai Co: Copper Basin Rd, 6 miles E of Skull Valley; 30.iii.2005; Coll. J. Booth	34 29′N, 112 35′W	adult female	*P. edulis*
M. acalyptus	JMB038	AZ Yavapai Co: 1.5 mi W of Mingus Mtn Pass, off of Hwy 89; 30.iii.2005; Coll. J. Booth	34°42′N, 112°11′W	adult female	*P. edulis*
M. acalyptus	JMB040	CA Kern Co: Frazier Park; 7.2001; Coll. J. Kelley	34 49′N, 118 56′W	nymphs	*P. monophylla*
M. bisetosus	JMB013	CA Shasta Co: Shingletown, 28244 Shingletown Ridge Rd.; 2.iv.2004; Colls. J. Booth and T. Kondo	40 28′N, 121 56′W	nymphs	*P. ponderosa*
M. bisetosus	JMB026	CA Nevada Co: Grass Valley, Empire Mines State Park; 9.iv.2004; Coll. J. Booth	39 12′N, 121 02′W	eggs	*P. ponderosa*
M. bisetosus	JMB029	CA San Diego Co: Mt.Laguna, Cleveland National Forest Visitor's Center; 1.v.2004; Coll. J. Booth	32 52′N, 116 25′W	nymphs	*P. coulteri*
M. gallicolus	JMB023	NY Suffolk Co: Manorville, Hwy 495, exit 70; 10.ix.2004; Coll. D. Gilrein	40°52′N, 72°48′W	adult female	*P. rigida*
M. gallicolus	JMB024	NY Suffolk Co: Riverhead, East Moriches Riverhead Road; i.ix.2004; Coll. J. Booth	40°55′N, 72°39′W	cyst	*P. rigida*
M. gallicolus	JMB036	MD Prince Georges' Co: Beltsville, USNM facility; 8.iii.2005; Colls. J. Booth and D. Miller	39 01′N, 76 53′W	eggs	*P. virginiana*
M. matsumurae	JMB014	Japan: Mie Prefecture, Shimagahara Village; 24.ii.2004; Coll. T. Kondo	34 46′N, 136 03′E	adult female	*P. thunbergii*
M. matsumurae	JMB047	China: Yitong County in Jilin Province, Northeast China; 25.v.2005; Coll. X. Yingping	42 20′N, 125 17′E	cyst	*P. thunbergii*
M. resinosae	JMB025	USA, NY Dutchess Co: Lafayetteville, Lafayetteville Multiple Use Area; 8.ix.2004; Coll. J. Booth	41°57′N, 73°44′W	cyst	*P. resinosa*
M. resinosae	JMB030	USA, CT Litchfield Co: Canaan, junction of Under Mountain and Cobble Roads; 27.viii.2004; Coll. C. Maier	40 01′N, 73 19′W	adult female	*P. resinosa*
M. thunbergianae	JMB021	South Korea: Naju City, Chollanamdo; 4.iii.2005; Coll. S.-C. Park	35 01′N, 126 43′E	adult female	*P. thunbergii*

using a Qiagen DNeasy® kit (Qiagen Inc., Valencia, California, U.S.A.). DNA was extracted non-destructively in many samples so that the cuticle could be saved for identification. In the remaining cases, a dead adult female found in association with the other life stages used for DNA extraction was preserved and mounted for identification. Identification was performed using published keys and descriptions (Kuwana 1905, Bean and Godwin 1955, Ray 1982, Miller and Park 1987, Foldi 2004) supported by knowledge of each species' known distribution and host-plant(s) and, in the case of *M. thunbergianae*, by the authorative identification of Seung-Chan Park who was one of the describers of this species (Miller and Park 1987). Standard methods for scale insect DNA analysis were utilized for molecular work (Cook et al. 2002, Downie and Gullan 2004). Targeted DNA sequences (Table 4) were obtained using Polymerase Chain Reaction, gel agarose DNA visualization, and automated DNA sequencing at the UC Davis Division of Biological Sciences DNA Sequencing Facility. Sequences were edited in Sequencher version 4.0.5 (Gene Codes Corp, Ann Arbor, Michigan, U.S.A.) and aligned in Se-Al (Rambaut 1996). PAUP* (Swofford 2003) was used for determining pairwise differences among species of *Matsucoccus*. As part of a larger phylogenetic project, sequence data from two nuclear ribosomal genes were analyzed (Booth, Cook, and Gullan, unpublished data). The markers examined were the small subunit ribosomal gene (SSU rDNA or 18S) and the D2, D3 and D10 expansion regions of the large subunit ribosomal gene (LSU rDNA or 28S) for a total of approximately 2,070 base pairs. These sequences were aligned and compared to assess the amount of genetic difference between purported species. Polymorphic sites within individuals were identified by examining electropherograms in Sequencher 4.0.5. Electropherograms of individuals within species were aligned in Sequencher 4.0.5 and examined to identify variable sites and indels.

Results and Discussion

Molecular evidence supports the synonymy of *M. matsumurae* and *M. resinosae* with the new inclusion of *M. thunbergianae*. Morphological analysis corroborates this information - no discernible consistent morphological differences are observed.

Nucleotide sequence data.—*Matsucoccus matsumurae*, *M. resinosae*, and *M. thunbergianae* had identical sequences for the18S and 28S D10 regions. The D2–D3 region of 28S revealed a total of four polymorphisms among these three species. This amount of divergence is similar to that seen in other *Matsucoccus* species in terms of polymorphic sites or intraspecific divergence, as exemplified by *M. acalyptus* Herbert, *M. bisetosus* Morrison, and *M. gallicolus* Morrison (Table 5). A pairwise difference comparison showed a maximum of 0.1% sequence difference in the D2–D3 region of 28S between *M. matsumurae*, *M. resinosae*, and *M. thunbergianae* (Table 6). This is less than the 0.8% recorded within *M. acalyptus*, 0.7% within *M. bisetosus* and 0.9% within *M. gallicolus* (Table 6). Maximum parsimony reconstruction revealed no phylogenetic structure among the individuals of *M. matsumurae, M. resinosae*, and *M. thunbergianae*. However, the clade containing *M. matsumurae*, *M. resinosae* and *M. thunbergianae* had 100 percent bootstrap support and Bayesian posterior probabilities value of 100 (Booth, Cook, and Gullan, unpublished data).

Morphology.—Many coccidologists have treated *M. matsumurae* and *M. resinosae* as synonyms based on morphology and life history data (Herbert 1921, Morrison 1928, Ray 1982, McClure 1983b, Kosztarab 1996) but no formal synonymy has been published

Table 3. Morphological features of adult females examined for cladistic analysis.

Morphological Characters	Character States
Size	(a) under 3 mm; (b) typically larger than 3 mm
Body Shape	(a) elongate-ovoid; (b) ovoid with two parallel lobes; (c) club shaped
Dorsum	
Bilocular tubular duct distribution	(a) on apical part of abdomen; (b) in rows on entire body
Cicatrix bands	(a) absent; (b) 1–4 bands; (c) ≥5 bands
Cicatrix diameter	(a) <9 μm; (b) 9–20 μm; (c) ≥25 μm
Venter	
Legs	(a) absent; (b) reduced; (c) fully developed
Antennal segmentation	(a) 2–3; (b) 4–8; (c) 9
Segment 5 of antennae with 1–2 fleshy setae	(a) absent; (b) present
Long trochanter setae	(a) 1 long setae; (b) 2 long setae; (c) 0 setae
Long setae near coxae	(a) absent; (b) present
Long setae midventrally on abdominal segments V–VII	(a) absent; (b) present
Abdominal spiracles	(a) 3 pairs; (b) >3 pairs
Multilocular disk pores	(a) absent; (b) present
Setae in marginal abdominal bands of bilocular ducts	(a) absent; (b) present

(see Ben-Dov 2005). Below we formally synonymize these three names. No discernible and consistent morphological differences were observed among specimens identified as *M. matsumurae*, *M. resinosae*, and *M. thunbergianae*. A review of the morphology of the adult females for a larger cladistic study (Booth, Cook and Gullan, unpublished) shows the three species to be identical based on 14 characters, including pore types, antennal morphology, and setal characters, typically used to distinguish species of *Matsucoccus* (Table 3). The description of *M. thunbergianae* recognizes this similarity (Miller and Park 1987), but notes that the main differences lie in the morphology of the adult male and several biological characteristics, as we explained in the introduction. The morphological differences among the males of the three species are primarily size differences. However, there is substantial overlap among the three species in the size ranges for all morphological features measured by Miller and Park (1987), including: penial sheath length, aedeagus length, length of antennal

Table 4. Genes and associated primers used for molecular analyses.

Gene	Region	Primer Sequence (5′–3′)	Primer Name	Primer Source
18S	24–585	CTGGTTGATCCTGCCAGTAG	18S–2880	Tautz et al. (1988)
		CCGCGGCTGCTGGCACCAGA	18S–B	von Dohlen and Moran (1995)
28S	D2–D3 expansion region	GAGAGTTMAASAGTACGTGAAAC	S3660	Dowton and Austin (1998)
		TCGGARGGAACCAGCTACTA	A335	Whiting et al. (1997)
	D10 expansion region	GAATGGATTAACGAGATTCTCAA	None	Modified from Dietrich et al. (2001)
		CACAATGATAGGAAGAGCC	None	Dietrich et al. (2001)

Table 5. Genetic differences among species for DNA sequences 18S and 28S.

Species		Number of Polymorphic Sites within Individuals	Number of Polymorphic Sites within Species
M. acalyptus			
	JMB037	0	5 sites + two indels
	JMB038	1	
	JMB040	0	
M. bisetosus			
	JMB013	0	6 sites; no indels
	JMB026	1	
	JMB029	0	
M. gallicolus			
	JMB023	0	1 site; no indels
	JMB024	1	
	JMB036	0	
M. matsumurae; M. resinosae; M. thunbergianae			
(matsumurae)	JMB014	1	4 sites; no indels
	JMB047	1	
(*resinosae*)	JMB025	1	
	JMB030	3	
(thunbergianae)	JMB021	1	

segments II–X, hind femur length, hind tibia length, forewing length, ratio of length of femur/length of tarsus, and length of longest tubular duct on abdominal segment VII.

Bean and Godwin (1955) differentiated adult females of *M. matsumurae* and *M. resinosae* based on life history and a subtle morphological disparity concerning the position at which the trachea enters the thoracic spiracles in the intermediate or cyst instar (Bean and Godwin 1955). Herbert (1921) had redescribed *M. matsumurae* based on both Japanese and American material. However, Herbert based his description partly on American material collected by Mr. J.G. Sanders from the host species *P. rigida* and *P. virginiana*. These pines are both known hosts of *M. gallicolus*, and not hosts of *M. resinosae* (Ben-Dov 2005). As a consequence of this confusion with *M. gallicolus*, Morrison (1928) even suggested that *M. matsumurae* may be indigenous to the Atlantic seaboard of the USA. Later, Morrison (1939) recognized this error and, in his original description of *M. gallicolus*, noted: "This is the insect which was figured and described (in part) by Herbert under the name *matsumurae*." Ray (1982) also lists Herbert's *M. matsumurae* as a synonym of *M. gallicolus*. This information was not included in the recent catalogue of the Margarodidae (Ben-Dov 2005).

Tang and Hao (1995) questioned the species concept of *M. matsumurae* used by American authors, partly because of the confusion created by Herbert's (1921) and Morrison's (1928) mixing up of *M. matsumurae* and *M. gallicolus*, and also because they surmised that there may be two species of *Matsucoccus* in Japan. Tang and Hao (1995) suggested that *M. thunbergianae* might be synonymous with Kuwana's (1905, 1907) concept of *M. matsumurae*, and that *M. resinosae* and *M. liaoningensis* Tang may be synonyms. They based their argument on purported differences in biology and adult body size of the two species pairs, but they were selective in their use of morphological data and their assertions cannot be supported.

In addition, certain morphological features in *Matsucoccus* can vary in response to environmental conditions. For example, Miller and Park (1987)

Table 6. Pairwise differences table (uncorrected): D2–D3 region of 28S.

	M. acalyptus (JMB002)	*M. acalyptus* (JMB037)	*M. acalyptus* (JMB038)	*M. acalyptus* (JMB039)	*M. acalyptus* (JMB040)	*M. bisetosus* (JMB013)	*M. bisetosus* (JMB026)	*M. bisetosus* (JMB029)
M. acalyptus (JMB002)								
M. acalyptus (JMB037)	0.001							
M. acalyptus (JMB038)	0.001	0.000						
M. acalyptus (JMB039)	0.004	0.003	0.003					
M. acalyptus (JMB040)	0.007	0.006	0.006	0.008				
M. bisetosus (JMB013)	0.111	0.109	0.111	0.107	0.112			
M. bisetosus (JMB026)	0.109	0.108	0.109	0.106	0.110	0.000		
M. bisetosus (JMB029)	0.115	0.114	0.116	0.112	0.116	0.007	0.007	
M. gallicolus (JMB023)	0.137	0.137	0.136	0.133	0.136	0.117	0.117	0.118
M. gallicolus (JMB024)	0.129	0.128	0.127	0.124	0.128	0.111	0.111	0.114
M. gallicolus (JMB036)	0.129	0.128	0.127	0.124	0.128	0.111	0.111	0.114
M. matsumurae (JMB047)	0.097	0.095	0.097	0.094	0.098	0.032	0.031	0.037
M. matsumurae (JMB014)	0.098	0.097	0.098	0.095	0.100	0.034	0.032	0.038
M. resinosae (JMB025)	0.099	0.097	0.098	0.095	0.100	0.034	0.033	0.038
M. resinosae (JMB030)	0.097	0.095	0.097	0.094	0.098	0.033	0.031	0.037
M. thunbergianae (JMB021)	0.099	0.098	0.099	0.096	0.100	0.034	0.033	0.039

	M. gallicolus (JMB023)	*M. gallicolus* (JMB024)	*M. gallicolus* (JMB036)	*M. matsumurae* (JMB047)	*M. matsumurae* (JMB014)	*M. resinosae* (JMB025)	*M. resinosae* (JMB030)
M. gallicolus (JMB024)	0.007						
M. gallicolus (JMB036)	0.009	0.000					
M. matsumurae (JMB047)	0.115	0.108	0.108				
M. matsumurae (JMB014)	0.117	0.110	0.110	0.000			
M. resinosae (JMB025)	0.115	0.108	0.108	0.001	0.001		
M. resinosae (JMB030)	0.116	0.108	0.108	0.000	0.000	0.000	
M. thunbergianae (JMB021)	0.118	0.111	0.110	0.000	0.000	0.001	0.000

examined the overwintering and summer generations of both *M. matsumurae* from China and *M. resinosae* from the U.S.A. and showed that the adult females of the overwintering generation of both species had more multilocular pores and larger cicatrices than the summer populations (Miller and Park 1987). Furthermore, morphological plasticity in body size and additional features has been observed for other species of *Matsucoccus* (Boratynski 1952, Ben-Dov 1981).

A fourth species of *Matsucoccus, M. pini* (Green), is found on a member of the *Pinus* subsection, namely *Pinus sylvestris* (Green 1925). This species is distributed throughout Europe and differs only subtly from *M. matsumurae* (Boratynski 1952, Foldi 2004). Boratynski (1952) indicates in his published key to the genus that the main difference between *M. matsumurae* and *M. pini* is the width of the dorsal cicatrices, the number of peripheral loculi in the multilocular pores, the host tree, and the country of origin. Foldi (2004) states that *M. matsumurae* and *M. pini* differ in the length of the bilocular tubular ducts and the number of multilocular pores at the apex of the abdomen. We examined the paralectotype females of *M. pini* housed at the BMNH and their morphology falls within the range of variation of *M. matsumurae*. Foldi (2004) states that the average body size for *M. pini* is 2.8 mm long, which is less than we recorded for

the specimens of *M. matsumurae* that we measured, however, Foldi also provides a greater body size range for *M. matsumurae* (2.5–4.5 mm long).

No specimens of *M. pini* were available for molecular analysis, but given the evidence of seasonal plasticity in size of cuticular features in *Matsucoccus*, the synonymy of *M. pini* with *M. matsumurae* seems likely. Other species that should be examined in this context are the Chinese species *M. dahuriensis* Hu and Hu described from *P. sylvestris var. mongolica* (Hu and Hu 1981), *M. liaoningensis* ex *P. tubulaeformis* (Tang 1978), *M. yunnanensis* Ferris ex *P. yunnanensis* (Ferris 1950), and the Russian species *M. boratynskii* Bodenheimer and Neumark ex *P. sylvestris* (Bodenheimer and Neumark 1955). These host *Pinus* species all belong to the same *Pinus* subsection (Gernandt et al. 2005) as *M. matsumurae* and appear morphologically similar to it based on available drawings of the adult females.

Matsucoccus matsumurae (Kuwana)

Xylococcus matsumurae Kuwana 1905: 91; Kuwana 1907: 209 (described again as "n. sp.").

Matsucoccus matsumurae: Cockerell 1909: 56 (change of combination).

Matsucoccus resinosae Bean and Godwin 1955: 166. **New synonymy**.

Matsucoccus thunbergianae Miller and Park 1987: 50. **New synonymy**.

Type material.—Syntypes of *Xylococcus matsumurae* Kuwana: JAPAN: Tokyo, at Sugamo, on bark of the trunk of pine-tree; collected May 20, 1903. The type specimens of *X. matsumurae* were destroyed in an earthquake in 1923 (Kuwana 1925, Tang and Hao 1995). Tang and Hao (1995) incorrectly refer to a holotype and paratypes of *X. matsumurae*; there is no evidence that Kuwana ever designated types and the so-called "paratypes" were collected 14 years after Kuwana's first description of the species. The latter specimens were collected by Kuwana outside of Tokyo, Japan, in 1919, whereas Kuwana's original collection was from Sugamo, Tokyo.

Holotype of *Matsucoccus resinosae* Bean and Godwin, adult female: USA: Connecticut, Easton, on *Pinus resinosa*, June 2, 1948, collected by George H. Plumb, label also with number "50.2156" (USNM). In their original description, Bean and Godwin (1955) referred to an adult female holotype as well as paratypes of different stages. However, no slides of the type series (all in the USNM) bear any label indicating which adult female is the designated holotype. There are two slides of adult females with collection data matching those given for the holotype in the original description; one slide has four adult females and the other has five, but neither slide has a type label of any kind. In the absence of an identifiable holotype, Ray (1982), in his unpublished dissertation, chose one specimen as the primary type and clearly indicated this information on the slide, but incorrectly labeled it "lectotype" instead of holotype. Here we properly label the previously unlabeled holotype (as recommended by F. Christian Thompson, personal communication to P. J. Gullan); the specimen is on the slide that has four adult females and is the second adult female from the right of the data label (body length: 4.2 mm; width: 2.2 mm). Paratypes of *M. resinosae*: various life stages including adult females (see Bean and Godwin 1955, page 169 for paratype information).

Holotype of *Matsucoccus thunbergianae* Miller and Park, adult female: SOUTH KOREA: Kohung, Chollanam-do, on *Pinus thunbergiana* (now *P. thunbergii*), collected December 1984, lab reared April 1984, collected by S.C. Park (USNM). Paratypes: 26 adult females, 36

adult males, 5 pupal males, 8 third-instar males, 25 first-instar nymphs: similar data to holotype (see Miller and Park 1987, page 50, for paratype information).

Diagnosis.—The adult female of *M. matsumurae* can be diagnosed by the following features: body 3.1–4.1 mm long, elongate-ovoid in shape; bilocular tubular ducts distributed in segmental rows on entire dorsum; 5 dorsal cicatrix bands on abdominal segments III to VII, cicatrix diameter 8–14 μm; antennae with 9 segments, segment V of antennae without fleshy setae; legs fully developed, one long (80–100 μm) trochanter seta, long setae (25–34 μm) near coxae on all pairs of legs; 7 pairs of abdominal spiracles; cluster of multilocular disk pores on ventral apex of abdomen; long setae (26–40 μm) midventrally on abdominal segments V–VII, and setae present in marginal abdominal bands of bilocular ducts.

Conclusion

Molecular and morphological data as well as host use, sex pheromones, and biogeography support the formal synonymy of *M. matsumurae*, *M. resinosae* and *M. thunbergianae*. The name *Matsucoccus matsumurae* (Kuwana) has nomenclatural priority. Additional species that should be considered for synonymy include *M. pini* and several other Eurasian species.

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